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(54) **SWITCHABLE AREA ENHANCEMENT FOR FLEXIBLE CAPACITIVE SENSING**

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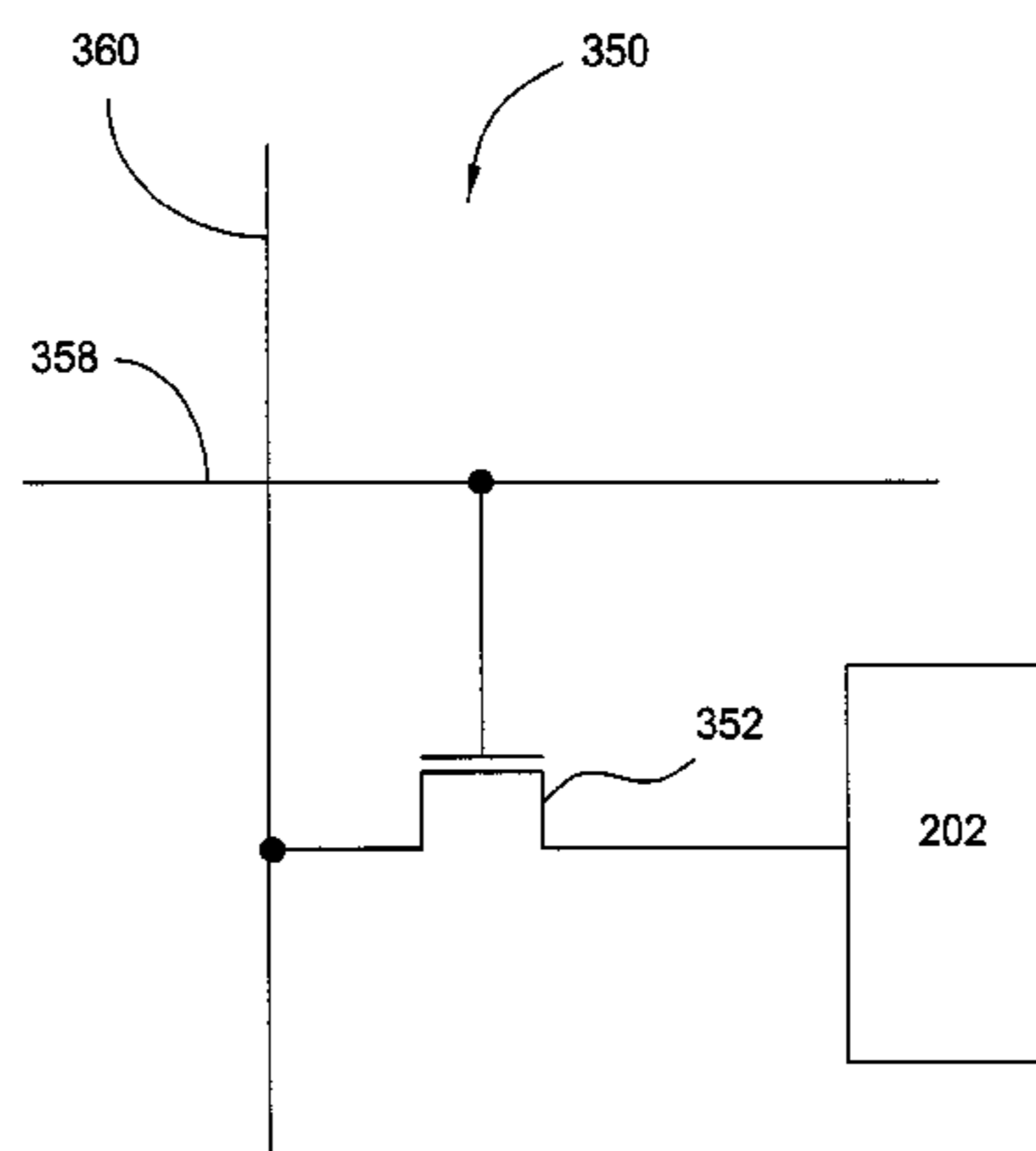
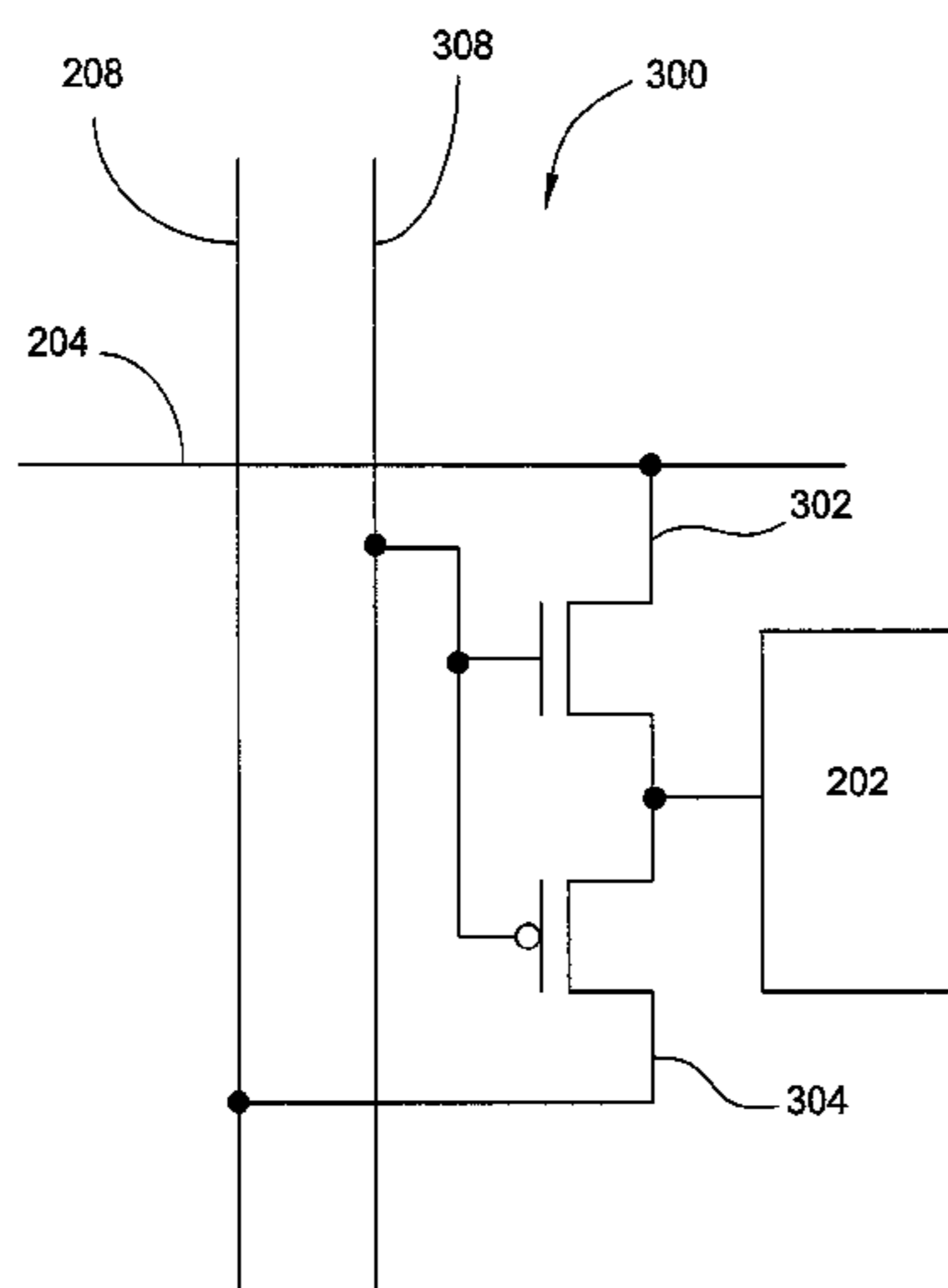
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(57) **ABSTRACT**

Embodiments of the invention generally provide an input device having a plurality of sensor electrodes that can be configured to be scanned in a first direction or a second direction. The input device includes a set of sensor electrodes and first and second sets of buses. The first buses are oriented in a first direction and the second buses are oriented in a second direction. The input device also includes a set of switching elements that are each configured to couple one of the sensor electrodes to either a bus in the first set of buses or a bus in the second set of buses. These embodiments allow the sensor electrodes to be scanned in a variety of patterns for flexible sensing functionality.

**19 Claims, 5 Drawing Sheets**



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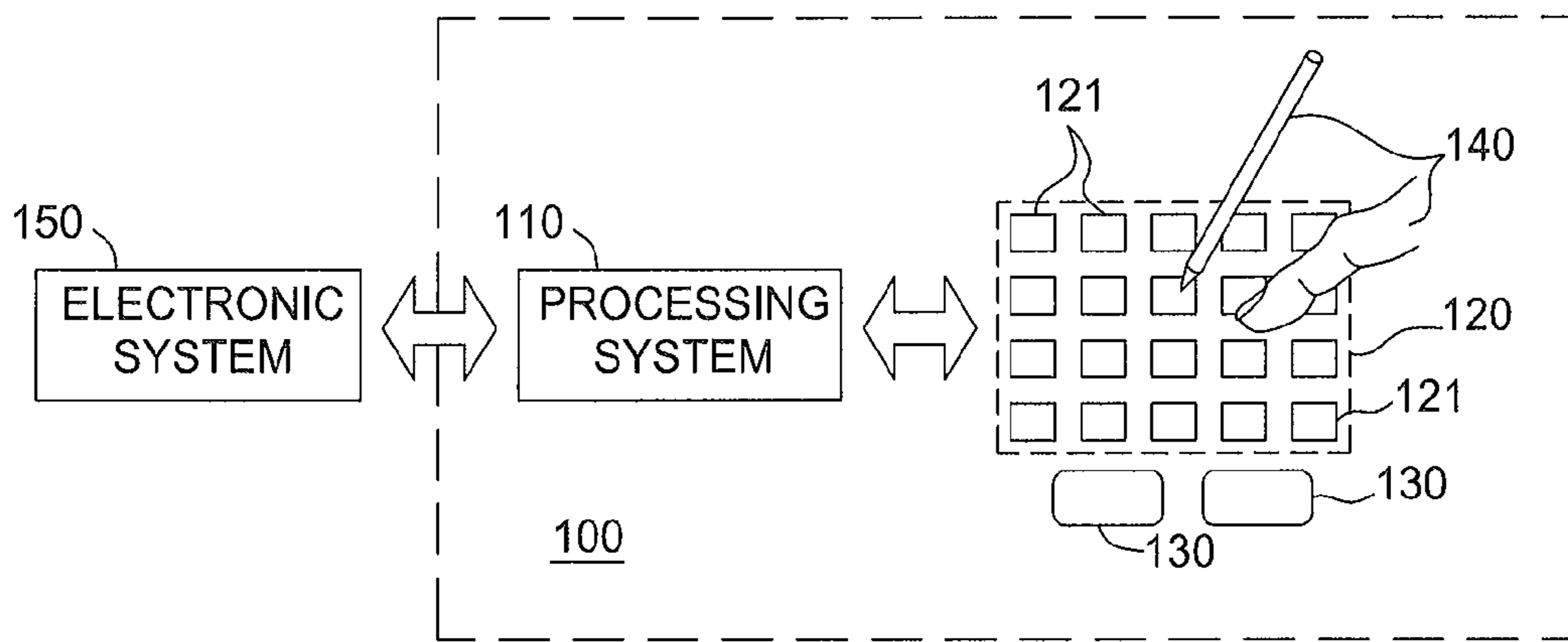


FIG. 1

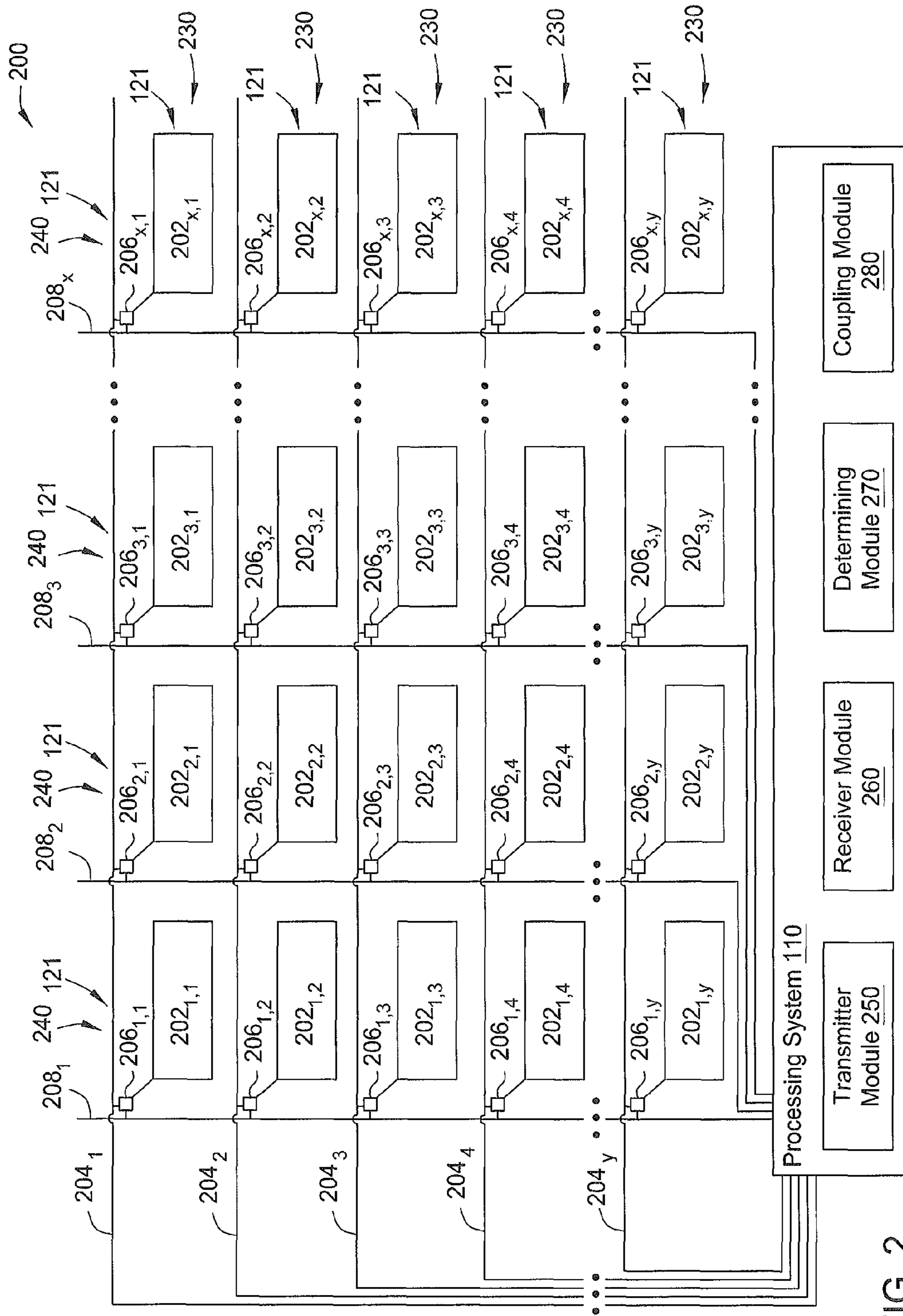


FIG. 2

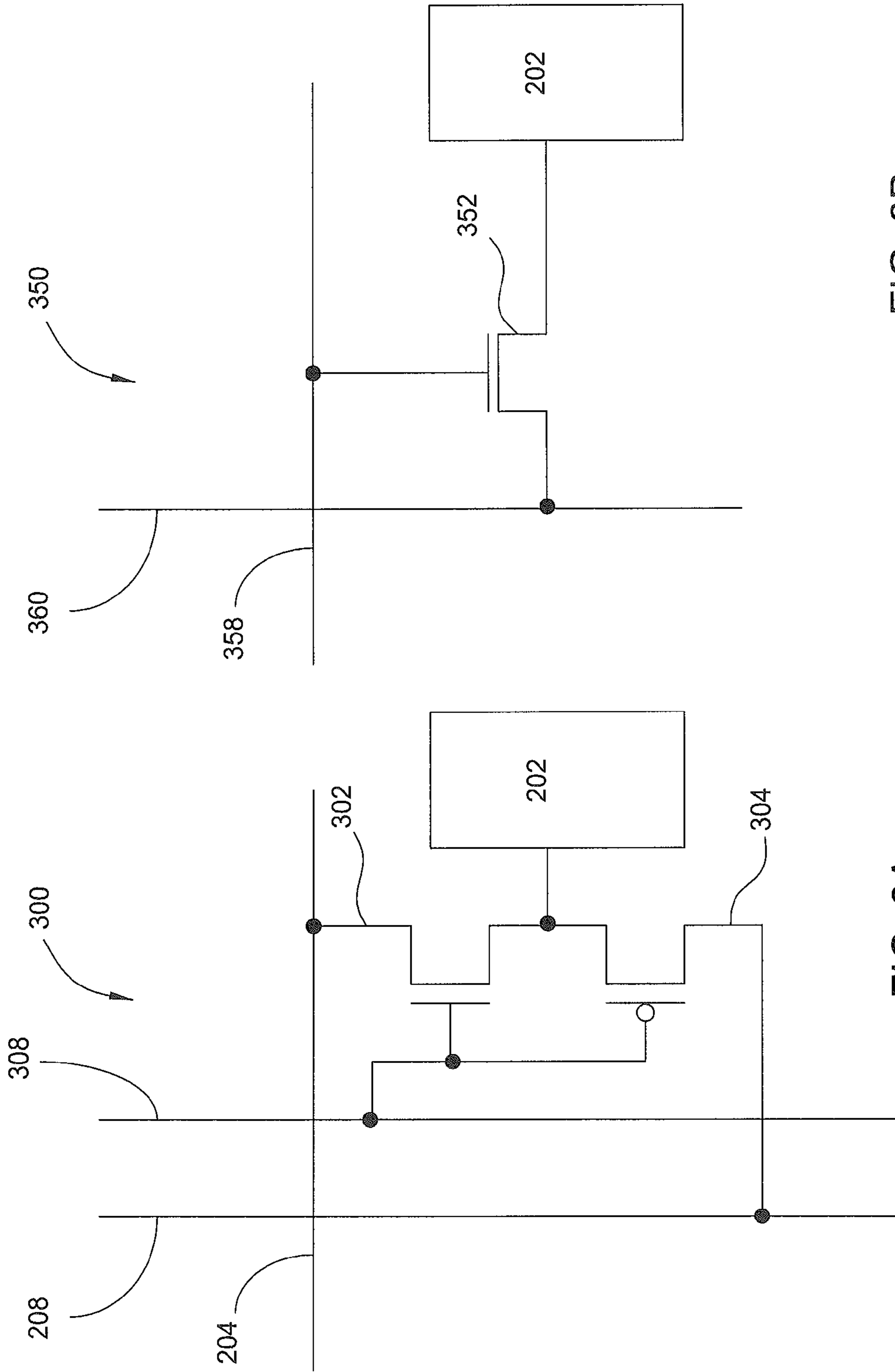


FIG. 3B

FIG. 3A

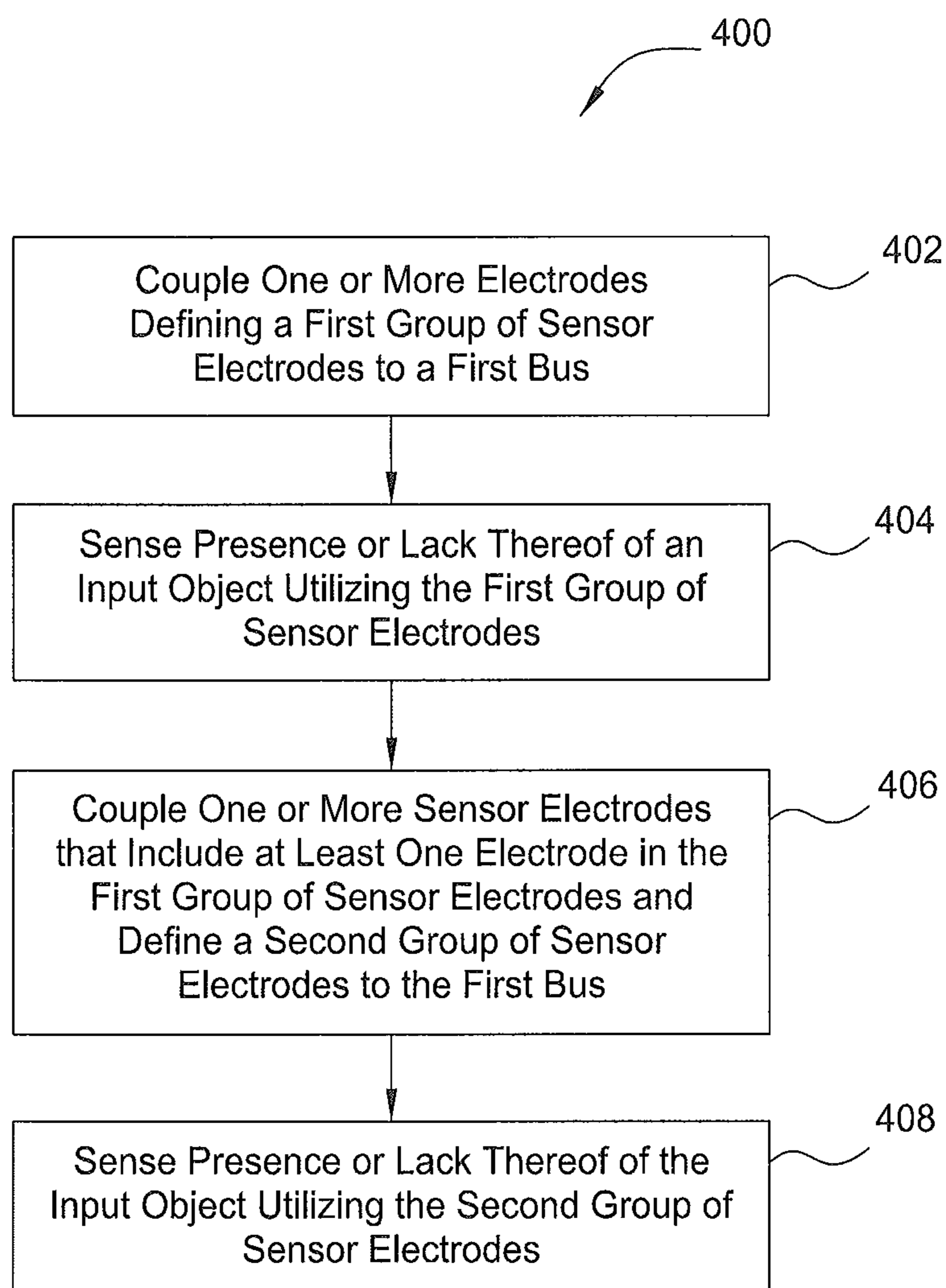


FIG. 4

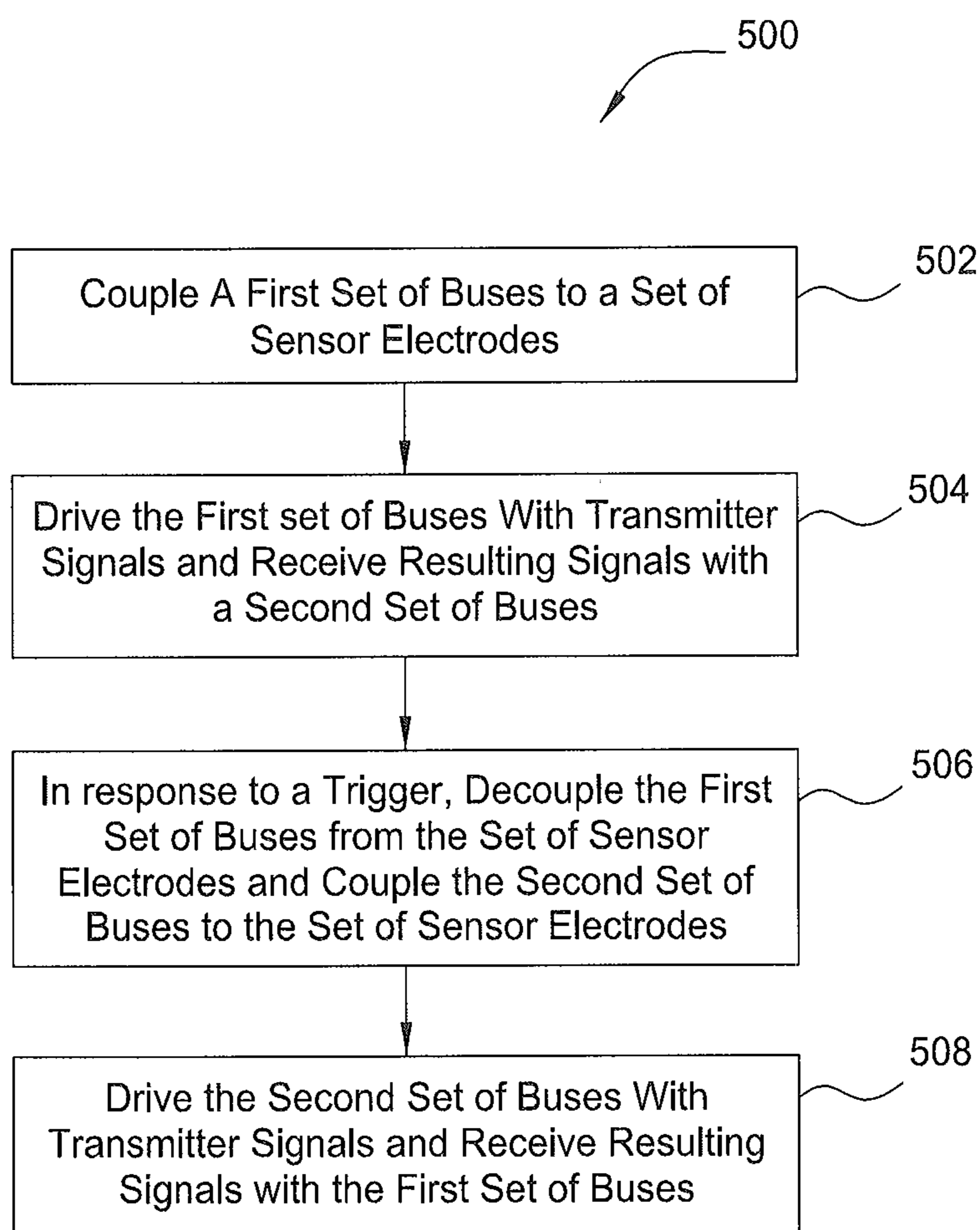


FIG. 5

## SWITCHABLE AREA ENHANCEMENT FOR FLEXIBLE CAPACITIVE SENSING

### BACKGROUND OF THE INVENTION

#### Field of the Invention

Embodiments of the present invention generally relate to a system and method for flexible sensor electrode utilization in a proximity sensing device.

#### Description of the Related Art

Touch sensor devices (also commonly called touch pads or touch screens) are widely used in a variety of electronic systems. A touch sensor device is typically a sensitive surface that uses capacitive, resistive, inductive, optical, acoustic or other technology to determine the presence, location and or motion of one or more fingers, styli, and/or other objects. The touch sensor device, together with a finger or other object provides an input to the electronic system. For example, touch sensor devices are used as input devices for computers, such as notebook computers.

Conventional touch sensor devices include transmitter electrodes arranged in a predefined pattern. To sense the presence of an input object, the transmitter electrodes are "scanned," typically in an order that is based on the direction in which the transmitter electrodes are oriented. For example, with horizontally oriented transmitter electrodes, the transmitter electrodes are scanned vertically, row-by-row. While such a configuration is simple to implement, having the transmitter electrodes locked in a predefined pattern will not provide robust sensing in many applications.

Therefore, there is a need for an improved touch sensor device.

### SUMMARY OF THE INVENTION

Embodiments of the invention generally provide a method and apparatus configured to allow input sensing using a plurality of sensor electrodes, wherein a pattern of sensor electrodes within the plurality of sensor electrodes may be selectively changed. A pattern may include any of one or more sensor electrodes within the plurality of sensor electrodes. Selectively changing the pattern may include varying the area or location of one or more electrodes during input sensing. These embodiments allow the sensor electrodes to be scanned in a variety of patterns for flexible sensing functionality.

In one embodiment, an input device is provided that includes a first plurality of buses selectively coupled to a plurality of sensor electrodes, a second plurality of buses ohmically separated from the first plurality of buses, and a plurality of switching elements. The second plurality of buses may be selectively coupled to the sensor electrodes. Each switching element in the plurality of switching elements is paired with a sensor electrode in the plurality of sensor electrodes. A first switching element in the plurality of switching elements is operable to couple the sensor electrode to either a first bus in the first plurality of buses or a second bus in the second plurality of buses.

In another embodiment, a processing system for an input device is provided that includes a transmitter module and a determining module. The transmitter module is configured to drive first signals with a first plurality of buses when the first plurality of buses is coupled to one or more sensor electrodes in a plurality of sensor electrodes. The transmitter module is also configured to drive second signals with a second plurality of buses when the second plurality of buses is coupled to the one or more sensor electrodes in the

plurality of sensor electrodes. The determining module is configured to determine presence or lack thereof of an input object based on signals received in response to driving signals with the first plurality of buses. The determining module is also configured to determine presence or lack thereof of the input object based on signals received in response to driving signals with the second plurality of buses.

In yet another embodiment, a method for operating an input device includes coupling one or more sensor electrodes defining a first group of sensor electrodes to a first bus, sensing presence or lack thereof of an input object utilizing the first group of sensor electrodes, coupling one or more sensor electrodes that include at least one electrode in the first group of sensor electrodes and define a second group of sensor electrodes to the first bus, and sensing presence or lack thereof of the input object utilizing the second group of sensor electrodes.

### BRIEF DESCRIPTION OF THE DRAWINGS

So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

FIG. 1 is a schematic block diagram of an exemplary input device, in accordance with embodiments of the invention.

FIG. 2 illustrates a stack-up of a sensor assembly that may be used in the input device to sense the input object, according to an embodiment described herein.

FIG. 3A illustrates a switching element for coupling a sensor electrode to either a first bus or a second bus, according to an embodiment described herein.

FIG. 3B illustrates a switching element for coupling a sensor electrode to either a first bus or a second bus, according to another embodiment described herein.

FIG. 4 is a flow diagram illustrating an exemplary method for driving a pattern of sensing elements, according to an embodiment described herein.

FIG. 5 is a flow diagram illustrating an exemplary method for driving a pattern of sensing elements, according to another embodiment described herein.

To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements disclosed in one embodiment may be beneficially utilized on other embodiments without specific recitation. The drawings referred to here should not be understood as being drawn to scale unless specifically noted. Also, the drawings are often simplified and details or components omitted for clarity of presentation and explanation. The drawings and discussion serve to explain principles discussed below, where like designations denote like elements.

### DETAILED DESCRIPTION

The following detailed description is merely exemplary in nature and is not intended to limit the invention or the application and uses of the invention. Furthermore, there is no intention to be bound by any expressed or implied theory



presented in the preceding technical field, background, brief summary or the following detailed description.

Embodiments of the invention generally provide an input device that includes sensor electrodes that may be selectively arranged in an arbitrary “sensing pattern.” Each of the sensing electrodes is selectively coupled to transmitter circuitry. The transmitter circuitry may drive one or more of the sensing electrodes in either a trans-capacitance mode or a self-capacitance mode. This configuration provides a flexible sensor array that can be scanned in an arbitrary manner so that at least one of the location or area of the sensing pattern may be selectively configured (i.e., changed) as desired, for example in response to a predefined touch or proximity event (or lack thereof).

FIG. 1 is a block diagram of an exemplary input device **100**, in accordance with embodiments of the invention. In FIG. 1, the input device **100** is a proximity sensor device (e.g., “touchpad,” “touch screen,” “touch sensor device”) configured to sense inputs provided by one or more input objects **140** positioned in a sensing region **120**. Example input objects include fingers and styli, as shown in FIG. 1. In some embodiments of the invention, the input device **100** may be configured to provide input to an electronic system **150**, which is sometime referred to herein as the “host.” As used in this document, the term “electronic system” (or “electronic device”) broadly refers to any system capable of electronically processing information. Some non-limiting examples of electronic systems include personal computers of all sizes and shapes, such as desktop computers, laptop computers, netbook computers, tablets, web browsers, e-book readers, and personal digital assistants (PDAs). Additional examples of electronic systems include composite input devices, such as physical keyboards that include input device **100** and separate joysticks or key switches. Further examples of electronic systems **150** include peripherals, such as data input devices (e.g., remote controls and mice) and data output devices (e.g., display screens and printers). Other examples include remote terminals, kiosks, video game machines (e.g., video game consoles, portable gaming devices, and the like), communication devices (e.g., cellular phones, such as smart phones), and media devices (e.g., recorders, editors, and players such as televisions, set-top boxes, music players, digital photo frames, and digital cameras). Additionally, the electronic system could be a host or a slave to the input device.

The input device **100** can be implemented as a physical part of the electronic system **150**, or can be physically separate from the electronic system. As appropriate, the input device **100** may communicate with parts of the electronic system **150** using any one or more of the following: buses, networks, and other wired or wireless interconnections. Examples include I<sup>2</sup>C, SPI, PS/2, Universal Serial Bus (USB), Bluetooth, RF, and IRDA.

Sensing region **120** encompasses any space above, around, in and/or near the input device **100** in which the input device **100** is able to detect user input by one or more input objects **140**. The sizes, shapes, and locations of particular sensing regions may vary widely from embodiment to embodiment. In some embodiments, the sensing region **120** extends from a surface of the input device **100** in one or more directions into space until signal-to-noise ratios prevent sufficiently accurate object detection. The distance to which this sensing region **120** extends in a particular direction, in various embodiments, may be on the order of less than a millimeter, millimeters, centimeters, or more, and may vary significantly with the type of sensing technology used and the accuracy desired. Thus, some embodiments

sense input that comprises no contact with any surfaces of the input device **100**, contact with an input surface (e.g., a touch surface) of the input device **100**, contact with an input surface of the input device **100** coupled with some amount of applied force or pressure, and/or a combination thereof. In various embodiments, input surfaces may be provided by surfaces of casings within which the sensor electrodes reside, by face sheets applied over the sensor electrodes or any casings, etc. In some embodiments, the sensing region **120** has a rectangular shape when projected onto an input surface of the input device **100**.

The input device **100** may utilize any combination of sensor components and sensing technologies to detect user input in the sensing region **120**. The input device **100** generally comprises one or more sensing elements **121** for detecting user input. As several non-limiting examples, the one or more sensing elements **121** in the input device **100** may use capacitive, elastive, resistive, inductive, magnetic acoustic, ultrasonic, and/or optical techniques to detect the position or motion of the input object(s) **140**. Some implementations are configured to provide sensing images that span one, two, three, or higher dimensional spaces.

In FIG. 1, a processing system **110** is shown as part of the input device **100**. The processing system **110** is configured to operate the hardware of the input device **100** to detect input in the sensing region **120**. The processing system **110** comprises parts of or all of one or more integrated circuits (ICs) and/or other circuitry components. In some embodiments, the processing system **110** also comprises electronically-readable instructions, such as firmware code, software code, and/or the like. In some embodiments, components composing the processing system **110** are located together, such as near sensing element(s) **121** of the input device **100**. In other embodiments, components of processing system **110** are physically separate with one or more components close to sensing elements **121** of input device **100**, and one or more components elsewhere. For example, the input device **100** may be a peripheral coupled to a desktop computer, and the processing system **110** may comprise software configured to run on a central processing unit of the desktop computer and one or more ICs (perhaps with associated firmware) separate from the central processing unit. As another example, the input device **100** may be physically integrated in a phone, and the processing system **110** may comprise circuits and firmware that are part of a main processor of the phone. In some embodiments, the processing system **110** is dedicated to implementing the input device **100**. In other embodiments, the processing system **110** also performs other functions, such as operating display screens, driving haptic actuators, etc.

The processing system **110** may be implemented as a set of modules that handle different functions of the input device **100**. Each module may comprise circuitry that is a part of the processing system **110**, firmware, software, or a combination thereof. In various embodiments, different combinations of modules may be used. In one example, modules include hardware operation modules for operating hardware such as sensing elements and display screens, data processing modules for processing data, such as sensor signals, and positional information, and reporting modules for reporting information. In another example, modules include sensor operation modules configured to operate sensing element(s) to detect input, identification modules configured to identify gestures such as mode changing gestures, and mode changing modules for changing operation modes.

In some embodiments, the processing system **110** responds to user input (or lack of user input) in the sensing

region **120** directly by causing one or more actions. In one example, as noted above, actions may include changing operation modes, as well as GUI actions, such as cursor movement, selection, menu navigation, and other functions. In some embodiments, the processing system **110** provides information about the input (or lack of input) to some part of the electronic system (e.g., to a central processing system of the electronic system that is separate from the processing system **110**, if such a separate central processing system exists). In some embodiments, some part of the electronic system process information received from the processing system **110** is used to act on user input, such as to facilitate a full range of actions, including mode changing actions and GUI actions. For example, in some embodiments, the processing system **110** operates the sensing element(s) **121** of the input device **100** to produce electrical signals indicative of input (or lack of input) in the sensing region **120**. The processing system **110** may perform any appropriate amount of processing on the electrical signals in producing the information provided to the electronic system. For example, the processing system **110** may digitize analog electrical signals obtained from the sensing elements **121**. As another example, the processing system **110** may perform filtering or other signal conditioning. As yet another example, the processing system **110** may subtract or otherwise account for a baseline set of data (e.g., baseline image), such that the information reflects a difference between the acquired electrical signals (e.g., sensing image) and the baseline. As yet further examples, the processing system **110** may determine positional information, recognize inputs as commands, recognize handwriting, and the like.

“Positional information” as used herein broadly encompasses absolute position, relative position, velocity, acceleration, and other types of spatial information. Exemplary “zero-dimensional” positional information includes near/far or contact/no contact information. Exemplary “one-dimensional” positional information includes positions along an axis. Exemplary “two-dimensional” positional information includes motions in a plane. Exemplary “three-dimensional” positional information includes instantaneous or average velocities in space. Further examples include other representations of spatial information. Historical data regarding one or more types of positional information may also be determined and/or stored, including, for example, historical data that tracks position, motion, or instantaneous velocity over time.

In some embodiments, the input device **100** is implemented with additional input components that are operated by the processing system **110** or by some other processing system. These additional input components may provide redundant functionality for input in the sensing region **120**, or some other functionality. FIG. 1 shows buttons **130** near the sensing region **120** that can be used to facilitate selection of items using the input device **100**. Other types of additional input components include sliders, balls, wheels, switches, and the like. Conversely, in some embodiments, the input device **100** may be implemented with no other input components.

In some embodiments, the input device **100** comprises a touch screen interface, and the sensing region **120** overlaps at least part of an active area of a display screen of a display device (not shown). For example, the input device **100** may comprise substantially transparent sensor electrodes overlaying the display screen and provide a touch screen interface for the associated electronic system. The display screen may be any type of dynamic display capable of displaying a visual interface to a user, and may include any type of light

emitting diode (LED), organic LED (OLED), cathode ray tube (CRT), liquid crystal display (LCD), plasma, electroluminescence (EL), or other display technology. The input device **100** and the display device may share physical elements. Some embodiments of the input device **100** include at least part of the display device. For example, some embodiments may utilize some of the same electrical components for displaying and sensing. In some examples, the display screen of the display device may be operated in part or in total by the processing system **110**.

It should be understood that while many embodiments of the present technology are described in the context of a fully functioning apparatus, the mechanisms of the present technology are capable of being distributed as a program product (e.g., software) in a variety of forms. For example, the mechanisms of the present technology may be implemented and distributed as a software program on information bearing media that are readable by electronic processors (e.g., non-transitory computer-readable and/or recordable/writable information bearing media readable by the processing system **110**). Additionally, the embodiments of the present technology apply equally regardless of the particular type of medium used to carry out the distribution. Examples of non-transitory, electronically readable media include various discs, memory sticks, memory cards, memory modules, and the like. Electronically readable media may be based on flash, optical, magnetic, holographic, or any other storage technology.

In many embodiments, the positional information of the input object **140** relative to the sensing region **120** is monitored or sensed by use of one or more sensing elements **121** (FIG. 1) that are positioned to detect its “positional information.” In general, the sensing elements **121** may comprise one or more sensing elements or components that are used to detect the presence of an input object. As discussed above, the one or more sensing elements **121** of the input device **100** may use capacitive, elastic, resistive, inductive, magnetic acoustic, ultrasonic, and/or optical techniques to sense the positional information of an input object. While the information presented below primarily discusses the operation of an input device **100**, which uses capacitive sensing techniques to monitor or determine the positional information of an input object **140** this configuration is not intended to be limiting as to the scope of the invention described herein, since other sensing techniques may be used.

In some resistive implementations of the input device **100**, a flexible and conductive first layer is separated by one or more spacer elements from a conductive second layer. During operation, one or more voltage gradients are created across the layers. Pressing the flexible first layer may deflect it sufficiently to create electrical contact between the layers, resulting in voltage outputs reflective of the point(s) of contact between the layers. These voltage outputs may be used to determine positional information.

In some inductive implementations of the input device **100**, one or more sensing elements pick up loop currents induced by a resonating coil or pair of coils. Some combination of the magnitude, phase, and frequency of the currents may then be used to determine positional information.

In one embodiment of the input device **100**, the sensing element **121** is a capacitive sensing element that is used to sense the positional information of the input object(s). In some capacitive implementations of the input device **100**, voltage or current is applied to the sensing elements to create an electric field between an electrode and ground. Nearby input objects **140** cause changes in the electric field, and

produce detectable changes in capacitive coupling that may be detected as changes in voltage, current, or the like. Some capacitive implementations utilize arrays or other regular or irregular patterns of capacitive sensing elements to create electric fields. In some capacitive implementations, portions of separate sensing elements may be ohmically shorted together to form larger sensor electrodes. Some capacitive implementations utilize resistive sheets, which may be uniformly resistive.

Some capacitive implementations utilize “self capacitance” (or “absolute capacitance”) sensing methods based on changes in the capacitive coupling between one or more sensing elements, or one or more sensor electrodes, and an input object. In various embodiments, an at least partially grounded input object positioned near the sensor electrodes alters the electric field near the sensor electrodes, thus changing the measured capacitive coupling of the sensor electrodes to ground. In one implementation, an absolute capacitance sensing method operates by modulating sensor electrodes with respect to a reference voltage (e.g., system ground), and by detecting the capacitive coupling between the sensor electrodes and the at least partially grounded input object(s).

Some capacitive implementations utilize “mutual capacitance” (or “transcapacitance”) sensing methods based on changes in the capacitive coupling between two or more sensing elements (e.g., sensor electrodes). In various embodiments, an input object near the sensor electrodes alters the electric field created between the sensor electrodes, thus changing the measured capacitive coupling. In one implementation, a transcapacitive sensing method operates by detecting the capacitive coupling between one or more transmitter sensor electrodes (also “transmitter electrodes,” “transmitting electrodes” or “transmitters”) and one or more receiver sensor electrodes (also “receiver electrodes” or “receiving electrodes”). Transmitter sensor electrodes may be modulated relative to a reference voltage (e.g., system ground) to transmit transmitter signals. Receiver sensor electrodes may be held substantially constant relative to the reference voltage to facilitate receipt of “resulting signals.” A “resulting signal” may comprise effect(s) corresponding to one or more transmitter signals, and/or to one or more sources of environmental interference (e.g., other electromagnetic signals). Sensor electrodes may be dedicated transmitters or receivers, or may be configured to both transmit and receive. In some implementations user input from an actively modulated device (e.g. an active pen) may act as a transmitter such that each of the sensor electrodes acts as a receiver to determine the position of the actively modulated device.

Most conventional multi-touch sensing sensor devices, in which the location of more than one finger or other input can be accurately determined, comprise a matrix of transmitter sensor electrodes and receiver sensor electrodes. Conventionally, during operation, capacitive images are formed by measuring the capacitance formed between each transmitter and receiver sensor electrode (referred to as “transcapacitance” or “mutual capacitance”), forming a matrix or grid of capacitive detecting elements across the sensing region **120**. The presence of an input object (such as a finger or other object) at or near an intersection between transmitter and receiver sensor electrodes changes the measured “transcapacitance”. These changes are localized to the location of object, where each transcapacitive measurement is a pixel of a “capacitive image” and multiple transcapacitive measurements can be utilized to form a capacitive image of the object.

Herein sensor design and sensing scheme embodiments are described that allow the creation of 2-D capacitance images using a single sensing layer in which all of the transmitting and receiving sensor electrodes are disposed in a single common layer with one another without the use of jumpers within the sensor area. The electronics to drive the sensor are located in a processing system, such as processing system **110** described herein. These described embodiments also facilitate contact sensing, proximity sensing, and position sensing. These described embodiments also facilitate “multi-touch” sensing, such as two finger rotation gestures and two finger pinch gestures, but with a less expensive sensor compared to a sensor that utilizes sensor electrodes in multiple layers. The reduced number of layers used to form the input device described herein versus other conventional position sensing devices also equates to fewer production steps, which in itself will reduce the production cost of the device. The reduction in the layers of the input device also decreases interference or obscuration of an image or display that is viewed through the sensor, thus lending itself to improved optical quality of the formed input device when it is integrated with a display device. Additional electrodes involved in sensing the shape of the electric fields of the transmitters and receivers, such as floating electrodes or shielding electrodes, may be included in the device and may be placed on other substrates or layers. The electrodes may be part of a display (share a substrate) and may even share functionality with the display (used for both display and sensing functionality). For example electrodes may be patterned in the Color filter of an LCD (Liquid Crystal Display) or on the sealing layer of an OLED (Organic Light Emitting Diode) display. Alternately, sensing electrodes within the display or on TFT (Thin Film Transistor) layer of an active matrix display may also be used as gate or source drivers. Such electrodes may be patterned (e.g. spaced or oriented at an angle relative to the pixels) such that they minimize any visual artifacts. Furthermore, they may use hiding layers (e.g. Black Mask between pixels) to hide at least some portion of one or more conductive electrodes.

FIG. **2** shows a portion of an exemplary pattern **200** of sensing elements **121** configured to sense in a sensing region **120** associated with the pattern **200**, according to some embodiments. For clarity of illustration and description, FIG. **2** shows the sensing elements **121** arranged in a pattern of simple rectangles. Further, FIG. **2** depicts an embodiment in which the pattern **200** of sensing elements **121** includes sensor electrodes **202**, first buses **204**, and second buses **208** are arranged in a grid pattern. In other embodiments, one or more of the sensor electrodes **202**, first buses **204**, and second buses **208** may be shaped and arranged in different patterns. For example, the sensor electrodes **202** may be hexagonal and form a hexagonal grid, among other patterns. In some embodiments, the sensor electrodes **202** are arranged in a regular, or repeating pattern. In some embodiments, the first buses **204** and second buses **208** are also arranged in a regular, or repeating, pattern.

In one embodiment, the first buses **204** are arranged orthogonally to the second buses **208**. The first buses **204** are ohmically isolated from the second buses **208**. That is, one or more insulators, such as a dielectric material or air gap, separate the first buses **204** from the second buses **208**. It is contemplated that the orientation of the buses **204**, **208** may be other than orthogonal.

The sensing elements **121** also include a switching element **206**. Each switching element **206** is configured to selectively couple either one of the first buses **204** or one of the second buses **208** to an associated one of the sensor

electrodes **202**. When one of the first buses **204** is coupled to the sensor electrode **202**, the first bus **204** may be configured to drive the sensor electrode **202** with signals. Similarly, when one of the second buses **208** is coupled to the sensor electrode **202**, the second bus **208** may be configured to drive the sensor electrode **202** with signals. Each sensor electrode **202** may be operated in a trans-capacitance or self-capacitance mode.

In trans-capacitance mode, a bus that is oriented in a first direction (for example, horizontally) is coupled to a sensor electrode **202** and drives the sensor electrode **202** with transmitter signals. A bus that is oriented in a second direction (for example, vertically) receives resulting signals that are generated as a result of driving the sensor electrode **202**. In other words, the bus oriented in the second direction, itself, acts as a receiver electrode when the bus oriented in the first direction is utilized to drive a signal onto the sensor electrode **202**. The capacitive coupling between the sensor electrode **202** and either the first bus **204** or second bus **208** (i.e., the bus not utilized to drive the sensor electrode **202**) changes with the proximity and motion of input objects in the sensing region associated with the sensor elements **121**, and thus affects the resulting signals that are received on the non-driven bus.

In trans-capacitance mode, the sensor electrodes **202** may be operated such that one sensor electrode **202** is driven alone with transmitter signals, or multiple sensor electrodes **202** are driven with transmitter signals at the same time. Where multiple sensor electrodes **202** are driven simultaneously, one or more of the first buses **204** or one or more of the second buses **208** may be driven with transmitter signals at the same time. Further, where multiple sensor electrodes **202** are driven simultaneously, the multiple sensor electrodes **202** may be driven with the same transmitter signal and produce an effectively larger transmitter electrode, or the multiple sensor electrodes **202** may be driven with different transmitter signals.

In self-capacitance mode, in one embodiment, a bus that is coupled to a sensor electrode **202** drives a sensor electrode **202** with a signal. In other embodiments not shown, other elements may drive the sensor electrodes while the bus receives signals in response. If an input object **140** is present, the electrical characteristics on that bus indicate an amount of capacitive coupling between the sensor electrode **202** and the input object **140**. As with trans-capacitance mode, in self-capacitance mode, any of first buses **204** or second buses **208** may be coupled to corresponding sensor electrodes **202** and may be configured to drive the sensor electrodes **202** with signals. Also, as with trans-capacitance mode, in self-capacitance mode, the sensor electrodes **202** may be operated such that one sensor electrode **202** is driven with signals alone, or multiple sensor electrodes **202** are driven with signals at the same time. Where multiple sensor electrodes **202** are driven simultaneously, one or more of the first buses **204** and/or one or more of the second buses **208** may be driven with signals at the same time.

In either self-capacitance mode or trans-capacitance mode, a set of measurements received from one or more of the first buses **204** or one or more of the second buses **208** form a “capacitive frame” representative of the capacitive couplings at each sensor electrode **202**. Multiple capacitive frames may be acquired over multiple time periods, and differences between them used to derive information about input in the sensing region. For example, successive capacitive frames acquired over successive periods of time can be used to track the motion(s) of one or more input objects entering, exiting, and within the sensing region.

In the embodiment depicted in FIG. 2, the processing system **110** includes a transmitter module **250**, a receiver module **260**, a determining module **270**, and a coupling module **280**. The transmitter module **250** includes transmitter circuitry for generating and providing signals to one or more of the first buses **204** and one or more of the second buses **208**, and for detecting changes in capacitance between a sensor electrode **202** and an input object **140** in self-capacitance mode. The receiver module **260** is configured to receive resulting signals through one or more of the first buses **204** and one or more of the second buses **208** in trans-capacitance mode, and may include receiver circuitry configured to receive the resulting signals.

The determining module **270** is configured to make determinations based on the signals received in response to driving to the first buses **204** or second buses **208** with signals. For example, the determining module may determine, based on signals received in response to driving a bus in the first buses **204** or a bus in the second buses **208**, the presence of an input object **140** in a sensing region **120** proximate the sensor electrodes **202**.

In some embodiments, a coupling module **280** is configured to selectively couple or decouple the transmitter module **250** and receiver module **260** from any of the first buses **204** or the second buses **208**. The coupling module may include one or more multiplexers configured to selectively couple one or more first buses **204** or second buses **208** to the transmitter module **250** or to the receiver module **260**. The multiplexers may be located in the processing system **110** or on the substrate on which the sensor electrodes **202** are deposited. The coupling module **280** may also be configured to transmit coupling signals to the switching elements **206** to cause the switching elements to independently couple a respective one of the sensor electrodes **202** to either a first bus **204**, a second bus **208**, or to none of the buses **204**, **208**.

Although FIG. 2 depicts an embodiment in which each first bus **204** is selectively coupled to a row **230** of sensor electrodes **202** and each second bus **208** is selectively coupled to a column **240** of sensor electrodes **202**, other configurations are contemplated. For example, each first bus **204** in the plurality of first buses, or each second bus **208** in the plurality of second buses may be coupled to a single one of the sensor electrodes **202**, or alternatively, to a plurality of the sensor electrodes **202**. When one of the buses **204**, **208** is coupled to a set of sensor electrodes **202**, the set of sensor electrodes **202** may be configured in a row, a column, a “square” of sensor electrodes **202**, a “rectangle” of sensor electrodes **202**, a diagonal line of electrodes **202**, or to any other combination of sensor electrodes **202**.

In some embodiments, arbitrary sensing patterns are possible. In other words, signals from transmitter module **250** may be driven to any combination of selected sensor electrodes **202** in order to sense capacitive coupling in either trans-capacitance or self-capacitance mode. Some example sensing patterns are described below.

In one exemplary sensing pattern, a group of sensor electrodes **202** are coupled to a common bus to form a larger sensor electrode. In a configuration in which multiple sensor electrodes **202** are coupled to a common bus to form a larger sensor electrode, each sensor electrode **202** is a sensor electrode element of the larger sensor electrode. In the exemplary sensing pattern, larger sensor electrodes are scanned two-by-two in a horizontal direction in trans-capacitance mode. In the following discussion, the two subscripts following reference numerals **202**, **204** and **206** refers to the X/Y position of the sensing elements **121** within the

pattern 200. More specifically, switching element 206<sub>1,1</sub> couples sensor electrode 202<sub>1,1</sub> to first bus 204<sub>1</sub> and switching element 206<sub>1,2</sub> couples sensor electrode 202<sub>1,2</sub> to first bus 204<sub>2</sub>. Subsequently, transmitter module 250 transmits transmitter signals to sensor electrodes 202<sub>1,1</sub> and 202<sub>1,2</sub> and the receiver module 260 receives resulting signals with second bus 208<sub>1</sub>. Switching element 206<sub>1,1</sub> then decouples sensor electrode 202<sub>1,1</sub> from first bus 204<sub>1</sub> and switching element 206<sub>1,2</sub> decouples sensor electrode 202<sub>1,2</sub> from first bus 204<sub>2</sub>.

Next, switching element 206<sub>2,1</sub> couples sensor electrode 202<sub>2,1</sub> to first bus 204<sub>1</sub> and switching element 206<sub>1,2</sub> couples sensor electrode 202<sub>2,2</sub> to first bus 204<sub>2</sub>. Subsequently, transmitter module 250 drives transmitter signals to sensor electrodes 202<sub>2,1</sub> and 202<sub>2,2</sub> and the receiver module 260 receives resulting signals with second bus 208<sub>2</sub>. Switching element 206<sub>2,1</sub> then decouples sensor electrode 202<sub>2,1</sub> from first bus 204<sub>1</sub> and switching element 206<sub>2,2</sub> decouples sensor electrode 202<sub>2,2</sub> from first bus 204<sub>2</sub>.

Next, switching element 206<sub>3,1</sub> couples sensor electrode 202<sub>3,1</sub> to first bus 204<sub>1</sub> and switching element 206<sub>3,2</sub> couples sensor electrode 202<sub>3,2</sub> to first bus 204<sub>2</sub>. Subsequently, transmitter module 250 drives transmitter signals to sensor electrodes 202<sub>3,1</sub> and 202<sub>3,2</sub> and the receiver module 260 receives resulting signals with second bus 208<sub>2</sub>. Switching element 206<sub>3,1</sub> then decouples sensor electrode 202<sub>3,1</sub> from first bus 204<sub>1</sub> and switching element 206<sub>3,2</sub> decouples sensor electrode 202<sub>3,2</sub> from first bus 204<sub>2</sub>.

The sequence of coupling and decoupling the sensor electrodes 202 is repeated until all the electrodes 202<sub>x,y</sub> are cycled through coupling to the transmitter module 250 and receiver module 260.

In another example sensing pattern, sensor electrodes 202 are driven in rows and then in columns in self-capacitance mode for profile sensing. More specifically, the corresponding switching elements 206 couple sensor electrode 202<sub>1,1</sub>, sensor electrode 202<sub>2,1</sub>, sensor electrode 202<sub>3,1</sub>, sensor electrode 202<sub>4,1</sub>, and so on, to first bus 204<sub>1</sub>. Further, the corresponding switching elements 206 couple sensor electrode 206<sub>1,2</sub>, sensor electrode 206<sub>2,2</sub>, sensor electrode 206<sub>3,2</sub>, and so on, to first bus 204<sub>2</sub>. Similarly, the corresponding switching elements 206 couple sensor electrodes 202 in the next row to first bus 204<sub>3</sub>, and so on. Subsequently, each row is driven with a signal and a signal is received in response.

After driving the sensor electrodes 202 in rows, the sensor electrodes are driven in columns. More specifically, the corresponding switching elements 206 couple sensor electrode 202<sub>1,1</sub>, sensor electrode 202<sub>1,2</sub>, sensor electrode 202<sub>1,3</sub>, sensor electrode 202<sub>1,4</sub>, and so on, to second bus 208<sub>1</sub>. Further, the corresponding switching elements 206 couple sensor electrode 206<sub>2,1</sub>, sensor electrode 206<sub>2,2</sub>, sensor electrode 206<sub>2,3</sub>, sensor electrode 206<sub>2,3</sub>, and so on, to second bus 208<sub>2</sub>. Similarly, the corresponding switching elements 206 couple sensor electrodes 202 in the next row to second bus 208<sub>3</sub>, and so on. Subsequently, each column is driven with a signal and a signal is received in response.

In another example sensing pattern, more than one row 230 or column 240 is driven at the same time in order to generate a coarse capacitive frame. If the coarse capacitive frame indicates the presence of an input object, then a finer capacitive frame may be generated. More specifically, after detecting the presence of an input object, the sensor electrodes 202 may be driven row-by-row or column-by-column only in the general area in which the input object was detected.

Certain scanning patterns are useful for certain applications. In one example, buttons are displayed on a touch screen that includes pattern 200. To detect the proximity of an input device 140 over each button, sensor electrodes 202 in the vicinity of each button are coupled to buses and are scanned together.

In some embodiments, the switching elements 206 may be configured to automatically couple a sensor electrode 202 to one of the first buses 204 or the second buses 208, based on which bus is being driven with a signal. In other words, applying a signal to a first bus 204 will cause a sensing electrode 202 to be coupled to that first bus 204. Similarly, applying a transmitter signal to a second bus 208 will cause a sensing electrode 202 to be coupled to that second bus 208.

In some embodiments, first buses 204 and second buses 208 are separated by insulative material disposed between them at cross-over areas; in such constructions, the first buses 204 and/or second buses 208 may be formed with jumpers connecting different portions of the same electrode. In some embodiments, first buses 204 and second buses 208 are separated by one or more layers of insulative material. In some other embodiments, first buses 204 and second buses 208 are separated by one or more substrates; for example, the first buses 204 and second buses 208 may be disposed on opposite sides of the same substrate, or on different substrates that are laminated together.

In some touch screen embodiments, sensor electrodes 202 comprise one or more common electrodes (e.g., “V-com electrode” or source drive electrode, gate electrodes or other display elements) used in updating the display of the display screen. These common electrodes may be disposed on an appropriate display screen substrate. For example, the common electrodes may be disposed on the TFT glass in some display screens (e.g., In Plane Switching (IPS) or Plane to Line Switching (PLS)), on the bottom of the color filter glass of some display screens (e.g., Patterned Vertical Alignment (PVA) or Multi-domain Vertical Alignment (MVA)), etc. In such embodiments, the common electrode can also be referred to as a “combination electrode”, since it performs multiple functions. In various embodiments, each sensor electrode 202 comprises one or more common electrodes. In other embodiments, at least two sensor electrodes 202 may share at least one common electrode.

In some embodiments, the sensing elements 121 do not include the switching elements 206. Rather, the switching elements 206 are located laterally outward of the plan area defined by the pattern 200 of the sensor electrodes 202. In such embodiments, the switching elements 206 may be grouped together on the same substrate as the sensing elements 121, but not within the pattern 200. In other embodiments, the switching elements 206 may be located within the processing system 110, or in the flex tail coupling the switching elements 206 to the processing system 110.

FIG. 3A illustrates a switching element 300 for coupling a sensor electrode 202 to either a first bus 204 or a second bus 208, according to an embodiment described herein. The switching element 300 may be utilized as the switching elements 206 depicted in FIG. 2. Switching element 300 includes a first transistor 302 and a second transistor 304. The first transistor 302 is an n-type transistor. The second transistor 304 is a p-type transistor. The source of the first transistor 302 is coupled to the first bus 204. The source of the second transistor 304 is coupled to the second bus 208. The gate of the first transistor 302 and the gate of the second transistor 304 are both coupled to the selector bus 308. The drain of the first transistor 302 and the drain of the second transistor 304 are coupled to each other and to the sensor electrode 202.

In some embodiments, the selector bus 308 may receive output from a comparator unit that detects a difference in voltage between a first bus 204 and a second bus 208. If the first bus 204 has a greater voltage than the second bus 208, then the output of the comparator unit is a high voltage. If the first bus 204 has a lower voltage than the second bus 208, then the output of the comparator unit is a low voltage. The voltage on the first bus 204 is greater than voltage on the second bus 208 when the first bus 204 is driven with a transmitter signal. Therefore, when the first bus 204 is driven with a transmitter signal, the first bus will automatically be coupled to the sensor electrode 202. Similarly, the voltage on the second bus 208 is greater than the voltage on the first bus 204 when the second bus 208 is driven with a transmitter signal. Therefore, when the second bus 208 is driven with a transmitter signal, the second bus 208 is automatically coupled to the sensor electrode 202. When utilized in a pattern 200 of sensing elements 121 as shown in FIG. 2, driving the voltage on one the buses 204, 208 may be utilized to serially connect a set of sensor electrodes 202 in a respective row 230 or column 240.

In other embodiments, the processing system 110 drives the selector bus 308 to cause the switching element 300 to couple either the first bus 204 or the second bus 208 to the sensor electrode 202. When the selector bus 308 is driven to a high voltage, the first transistor 302 passes current from the first bus 204 to the sensor electrode 202, but the second transistor 304 passes negligible current from the second bus 208 to the sensor electrode 202. Therefore, a transmitter signal applied to the first bus 204 can drive the sensor electrode 202.

FIG. 3B illustrates a switching element 350 for coupling a sensor electrode 202 to either a first bus 204 or a second bus 208, according to an embodiment described herein. The switching element 350 may also be utilized as the switching elements 206 depicted in FIG. 2.

Switching element 350 includes a transistor 352. The gate of the transistor 352 is coupled to a selector bus 358 and the source of the first transistor is coupled to an input bus 360. The drain of the transistor 352 is coupled to the sensor electrode 202. The input bus 360 transmits a signal either from a first bus 204 or a second bus 208.

Each sensing element 121 may include two or more of the switching elements 350. The source of a first switching element 350 is coupled to a first bus 204 and the source of a second switching element 350 is coupled to a second bus 208. The selector bus 358 selects input from either of the first bus 204 or the second bus 208. The drain of the transistor 352 in both of the switching elements 350 is coupled to the sensor electrode 202.

In some embodiments, the selector bus 358 is coupled to a comparator unit that compares whether the voltage on the bus coupled to the source of the transistor 352 is greater than a threshold level. If the voltage is greater, than the comparator unit provides a high voltage to the gate of the transistor 352, which causes the transistor to pass the signal on the bus.

FIG. 4 is a flow diagram illustrating an exemplary method 400 for driving a pattern of sensor electrodes, according to an embodiment described herein. Although the method 400 is described in conjunction with FIGS. 1-3, persons skilled in the art will understand that any system configured to perform the method, in any order, falls within the scope of the present invention, and with other patterns of sensor electrodes 202.

The method 400 begins at step 402, where one or more switching elements selectively couple one or more sensor

electrodes 202 defining a first group of sensor electrodes to a first bus 204. At step 404, the processing system 110 senses the presence or lack thereof of an input object 140 utilizing the first group of sensor electrodes. The sensing step 404 may drive the first group of sensor electrodes for either absolute or transcapacitance sensing. At step 406, one or more switching elements 206 selectively couple one or more of the sensor electrodes 202 that include at least one electrode defining the first group of sensor electrodes 202 to define a second group of sensor electrodes 202, the second group of sensor electrodes 202 coupled to the first bus through the switching elements 206. The second group of sensor electrodes 202 has a pattern that is different in at least one of location or area compared to the pattern of the first group of sensor electrodes 202. Step 406 may be initiated by a predefined event, such as in response to a predefined touch or proximity event (or lack thereof) of an input object in a sensing region or other event. A predefined touch or proximity event may include a sensing finger being detected in an absolute sensing mode. At step 408, the processing system 110 senses the presence or lack thereof of the input object utilizing the second group of sensor electrodes 202. The sensing step 408 may drive the second group of sensor electrodes for either absolute or transcapacitance sensing. In one embodiment, the sensing step 404 may drive the first group of sensor electrodes for absolute sensing while the sensing step 408 may drive the second group of sensor electrodes for transcapacitance sensing.

FIG. 5 is a flow diagram illustrating exemplary method 500 for driving a pattern of sensor electrodes, according to another embodiment described herein. Although the method 500 are described in conjunction with FIGS. 1-3, persons skilled in the art will understand that any system configured to perform the method steps, in any order, falls within the scope of the present invention.

The method 500 begins at step 502 where a first set of buses is coupled to a set of sensor electrodes to form a pattern. In step 504, the first set of buses is driven with transmitter signals and resulting signals are received with a second set of buses. In step 506, in response to a predefined event, the first set of buses are decoupled from the first set of sensor electrodes and the second set of buses are coupled to the first set of sensor electrodes. In step 508, the second set of buses is driven with transmitter signals and resulting signals are received with the first set of buses.

Advantageously, using switching elements to variably couple either first traces or second traces to sensor electrodes results in the ability to scan an input device in a variety of selectable configurations to utilize different size, location and geometry of the sensor electrodes comprising the pattern could to the processing system, thereby providing flexibility to configure the sensor as desired to better address real time sensing needs.

Thus, the embodiments and examples set forth herein were presented in order to best explain the present invention and its particular application and to thereby enable those skilled in the art to make and use the invention. However, those skilled in the art will recognize that the foregoing description and examples have been presented for the purposes of illustration and example only. The description as set forth is not intended to be exhaustive or to limit the invention to the precise form disclosed.

While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

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What is claimed is:

1. An input device comprising:
  - a plurality of sensor electrodes;
  - a first plurality of buses selectively coupled to the plurality of sensor electrodes;
  - a second plurality of buses ohmically separated from the first plurality of buses, the second plurality of buses selectively coupled to the sensor electrodes;
  - a plurality of switching elements, wherein each switching element in the plurality of switching elements is paired with a sensor electrode in the plurality of sensor electrodes, and wherein a first switching element in the plurality of switching elements is operable to couple the sensor electrode to either a first bus in the first plurality of buses or a second bus in the second plurality of buses; and
  - a processing system coupled to the first plurality of buses and coupled to the second plurality of buses, the processing system configured to:
    - drive signals with one or more buses in the first plurality of buses when the one or more buses in the first plurality of buses are selectively coupled to the plurality of sensor electrodes, and
    - drive signals with one or more buses in the second plurality of buses when the one or more buses in the second plurality of buses are selectively coupled to the plurality of sensor electrodes.
2. The input device of claim 1, wherein the buses in the first plurality of buses are arranged in a regular pattern.
3. The input device of claim 1, wherein the pairs of switching elements and sensor electrodes are arranged in a regular pattern.
4. The input device of claim 1, wherein the plurality of switching elements are located laterally outward of the plurality of sensor electrodes.
5. The input device of claim 1, wherein each switching element comprises:
  - a transistor operable to selectively couple one of the buses to the paired sensor electrode.
6. The input device of claim 1, wherein the first plurality of buses and the second plurality of buses are selectively coupled to transmitter circuitry of a transmitter module of the processing system.
7. The input device of claim 1, wherein the first plurality of buses and the second plurality of buses are selectively coupled to a receiver module of the processing system.
8. The input device of claim 1, wherein the processing system further comprises:
  - a determining module configured to:
    - determine presence or lack thereof of the input object in response to driving the signals with one or more buses in the first plurality of buses, and
    - determine presence or lack thereof of the input object in response to driving the signals with one or more buses in the second plurality of buses.
9. The input device of claim 1, wherein the processing system is further configured to:
  - drive transmitter signals with the first plurality of buses when the first plurality of buses is coupled to one or more sensor electrodes in the plurality of sensor electrodes, and
  - receive resulting signals with the second plurality of buses when the second plurality of buses is coupled to one or more sensor electrodes in the plurality of sensor electrodes.
10. The input device of claim 1, wherein the processing system is further configured to:

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- drive transmitter signals with the second plurality of buses when the second plurality of buses is coupled to one or more sensor electrodes in the plurality of sensor electrodes, and
  - receive resulting signals with the first plurality of buses when the first plurality of buses is coupled to one or more sensor electrodes in the plurality of sensor electrodes.
11. The input device of claim 1, wherein the processing system is further configured to:
    - drive signals with the first plurality of buses and receive signals with the first plurality of buses in response, when the first plurality of buses is coupled to one or more sensor electrodes in the plurality of sensor electrodes, and
    - drive signals with the second plurality of buses and receive signals with the second plurality of buses in response, when the second plurality of buses is coupled to one or more sensor electrodes in the plurality of sensor electrodes.
  12. The input device of claim 1, wherein at least one switching element in the plurality of switching elements is configured to simultaneously couple a first bus of the first plurality of buses to two or more sensor electrodes of the plurality of sensor electrodes.
  13. A processing system for an input device, the processing system comprising:
    - a coupling module comprising coupling circuitry configured to:
      - couple one or more sensor electrodes in a plurality of sensor electrodes to a first bus, and
      - couple the one or more sensor electrodes to a second bus;
    - a transmitter module comprising transmitter circuitry configured to:
      - drive first signals on the first bus when the first bus is coupled to the one or more sensor electrodes, wherein driving the first signals causes the first bus to be coupled to the one or more sensor electrodes, and
      - drive second signals on the second bus when the second bus is coupled to the one or more sensor electrodes wherein driving the second signals causes the second bus to be coupled to the one or more sensor electrodes; and
    - a determining module configured to:
      - determine presence or lack thereof of an input object based on signals received in response to driving signals on the first bus when the first bus is coupled to the one or more sensor electrodes; and
      - determine presence or lack thereof of the input object based on signals received in response to driving signals on the second bus when the second bus is coupled to the one or more sensor electrodes.
  14. The processing system of claim 13, further comprising:
    - a receiver module configured to:
      - receive first resulting signals with the second bus when the first bus is coupled to one or more sensor electrodes, and
      - receive second resulting signals with the first bus when the second bus is coupled to one or more sensor electrodes.
  15. The processing system of claim 13, wherein the transmitter module is further configured to:
    - receive signals with the first bus when driving the first bus with the first signals; and

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receive signals with the second bus when driving the second bus with the second signals.

**16.** The processing system of claim **13**, further comprising:

switching circuitry configured to:  
 couple the one or more sensor electrodes to the first bus, and  
 couple the one or more sensor electrodes to the second bus.

**17.** A method for operating an input device, the method comprising:

driving first signals on a first bus, thereby coupling to the first bus one or more sensor electrodes to define a first group of sensor electrodes;

sensing presence or lack thereof of an input object utilizing the driven first signals and the first group of sensor electrodes;

coupling to the first bus one or more sensor electrodes that include at least one sensor electrode of the first group to define a second group of sensor electrodes, the first

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and second groups of sensor electrodes different in one or more of number or position of the sensor electrodes; and

sensing presence or lack thereof of the input object utilizing the second group of sensor electrodes.

**18.** The method of claim **17**, wherein:  
 sensing presence or lack thereof of the input object utilizing the first group of sensor electrodes comprises:  
 coupling the first bus to transmitter circuitry;  
 coupling a second bus to a receiver module;  
 driving the first bus with a transmitter signal; and  
 receiving resulting signals with the second bus.

**19.** The method of claim **17**, wherein:  
 sensing presence or lack thereof of the input object utilizing the first group of sensor electrodes comprises:  
 coupling the first bus to transmitter circuitry;  
 driving the first bus with a signal; and  
 determining a capacitive coupling measurement between the first group of sensor electrodes and the input object.

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